another generation may possibly pass away before either the House of Commons or even Ministers are sufficiently instructed in science to recognize fully their responsibility in this direction.

Whatever, then, the future may bring, the last twenty years have been characterized by progress both steady and rapid. The tide flows on with no sign of check, and we accept the success of NATURE in no spirit of self-gratulation, but as a straw by which the speed of the current may be gauged.

MODERN VIEWS OF ELECTRICITY.

Modern Views of Electricity. By Oliver J. Lodge, D.Sc., LL.D, F.R.S. (London: Macmillan and Co., 1889.)

IN this interesting book Prof. Lodge gives a very lively and graphic account of many of the most recent speculations about the nature of electrical phenomena. A work with this object was urgently needed, as the method of regarding these phenomena given in popular treatises on electricity is totally different from that used by those engaged in developing the subject.

The attention called by Faraday and Maxwell to the effects produced by and in the medium separating electrified bodies has had the effect of diverting attention from the condition of the charged bodies in the electric field to that of the medium separating them, and it is perhaps open to question whether this of late years has not been too much the case. To explain the effects observed in the electric field we should require to know the condition not only of the ether, but also of the conductors and insulators present in it; just as a complete theory of light would include the state of the luminous bodies as well as of the ether transmitting the radiations excited by them. Since matter is more amenable to experiment than the ether, it seems most probable that we shall first gain an insight into the nature of electricity from a study of those cases where matter seems to play the chief part—such as in the electric discharge through gases, and the phenomena of electrolysis—rather than from speculations, however interesting, as to what takes place in the ether when it is transmitting electrical vibrations. Prof. Lodge, however, in the work under consideration, devotes most of his space to the consideration of the ether. In his preface he says, "Few things in physical science appear to me more certain than that what has so long been called electricity is a form, or rather a mode, of manifestation of the ether;" and he proceeds to give precision to this somewhat vague statement by developing a theory that electricity is a fluid, and a constituent of a very complex ether. In the first few chapters he supposes that all insulators, including the ether, have a cellular structure the cells being filled with a fluid which is electricity, and which is not able to get from one cell to another unless the walls of the cells are broken down; in conductors, however, there are channels between the cells, so that the electricity is able to flow more or less freely through them. A flow of this fluid is an electric current. But if this is the case, anything which sets the ether in motion will produce an electric current. Now, Fizeau's experiments show that moving bodies carry the ether with them to an extent depending on their index of refraction; so that a disk made of glass or other refracting substance, if set in rapid rotation about an axis through its centre, and at right angles to its plane, ought to act as if currents were circulating in the disk, and produce a magnetic field around it. In order to avoid the allied difficulty that nothing has ever been observed which indicates that a magnet or a current flowing through a coil possesses gyroscopic properties, Prof. Lodge assumes, in subsequent chapters, that the fluid in the cells of the ether is a mixture of two fluids, and that these two fluids are positive and negative electricity: and that, in order to exhibit any electrical effect, the compound fluid has first to be decomposed into positive and negative electricity by the application of an electromotive force. A current of electricity, on this view, consists of the flow of equal quantities of positive and negative electricity in opposite directions. Thus this, the most "modern view of electricity," is in its most important features almost identical with the old two-fluid theory published by Symmer in 1759. We confess we do not think the theory in its present form advances the science of electricity much: it does not suggest new phenomena, nor does it lend itself readily to explain the action of matter in modifying electrical phenomena; it demands, too, a very artificial ether. It would seem that the first steps required to make a theory of this kind a real advance on the old two-fluid theory would be the discovery of a structure for the ether, which would possess the same kind of properties as the mixture of the two electricities on that theory. A great deal, too, is left indefinite in the theory: thus, for example, we are not told whether for a given current these streams are moving slowly or with prodigious velocities. In fact, there is throughout the book rather a want of definite conclusions, and this is rather hidden by the vigorous style in which Prof. Lodge writes: he develops his ideas in such an enthusiastic and interesting way that on the first reading they seem to be a good deal more definite than they prove to be on calmer reflection.

But whatever may be thought of Prof. Lodge's theory of electricity, there can be, we think, no two opinions of the value of the numerous models illustrating the properties of electrical systems which he has invented. These must prove of the greatest assistance in enabling the student to gain a clear and vivid idea of electrical processes, and ought to be largely employed by all teachers of electricity.

In a work dealing so briefly with such a multitude of different and difficult subjects it is natural that there should be many statements to which exception might be taken. Prof. Lodge disarms criticism by his frank admission of this; sometimes, also, by an amusing vagueness of statement: thus, on p. 206, in speaking of the condition of the ether inside a strongly-magnetizable substance, he says: "Perhaps it is that the atoms themselves revolve with the electricity; perhaps it is something quite different." There are, however, some statements of a less theoretical kind which seem to us likely to mislead the student. Thus it is stated that the amount of the Peltier effect shows that the difference of potential between zinc and copper is only a few micro-volts. The Peltier effect, however, without further assumption, cannot tell us anything about the absolute magnitude of the difference of

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potential between the metals; it can only give us the value of the temperature coefficient, which is equal to the Peltier effect divided by the absolute temperature. Then, again, the pyro-electricity of tourmaline is explained by the unilateral conductivity of a tourmaline crystal whose temperature is changing, discovered by the author and Prof. Silvanus Thompson. If this unilateral conductivity is regarded as proving the existence of an electromotive force in a crystal which is increasing or decreasing in temperature, the explanation is valid, but in the text nothing is said about an electromotive force, and the student might be led to infer that a mere difference in resistance could explain pyro-electricity. The way in which a current flows past an insulating obstacle, the lines of flow closing in on the obstacle, and leaving nothing corresponding to "dead water" behind it, is given as a proof that the electric current has no mechanical momentum; but unless the corners of the obstacle were infinitely sharp, a slowly-moving fluid might flow in the same way as electricity, even though it possessed inertia, so that the proof is not conclusive. It is also stated that the effects on light produced by a magnetized body, discovered by Dr. Kerr, of Glasgow, have been deduced by Prof. Fitzgerald from Maxwell's theory of light. As a matter of fact, however, the results deduced from this theory by Fitzgerald do not coincide with those observed by Dr. Kerr and Prof. Kundt. The production in an unequally-heated conductor of an electromotive force is explained by supposing the atoms in such a body to be moving faster in one direction than the opposite, and therefore, since they are supposed to drag the ether with them, producing a flow of ether in the direction in which they are moving fastest; but, on the dualistic theory of electricity adopted in this book, this ether stream would consist of equal quantities of positive and negative electricity moving in the *same* direction, and this would not produce any electrical effect.

At the end of the book are three popular lectures delivered by Prof. Lodge, the first on the relation between electricity and light, the second on the ether and its functions, and the third his admirable one at the Royal Institution, on the discharge of a Leyden jar, which is a model of what such a lecture ought to be.

Taken as a whole, we think that the book is one which ought to be read by all advanced students of electricity; they will get from it many of the views which are guiding those who are endeavouring to advance that science, and it is so stimulating that no one can read it without being inspired with a desire to work at the subject to which it is devoted.

THE CALCULUS OF PROBABILITIES.

Calcul des Probabilités. Par J. Bertrand. (Paris: Gauthier-Villars, 1889.)

"EVERYBODY makes errors in Probabilities at times, and big ones," writes De Morgan to Sir William Hamilton. M. Bertrand appears to form an exception to this dictum, or at least to its severer clause. He avoids those slips in the philosophical part of the subject into which the greatest of his mathematical predecessors have fallen. Thus he points out that, in investigating the "causes" of an observed event, or the ways in which it might have happened, by means of the calculus of probabilities, it is usual to make certain unwarranted assumptions concerning the so-called *a priori* probability of those causes. Suppose that a number of black and white balls have been drawn at random from an urn, and from this datum let us seek to determine the proportion of black and white balls in the urn. It is usual to assume, without sufficient grounds, that *a priori* one proportion of balls, one constitution of the urn, is as likely as another. Or suppose a coin has been tossed up a number of times, and from the observed proportion of heads and tails let it be required to determine whether and in what degree the coin is loaded. Some assumption must be made as to the probability which, prior to, or abstracting from, our observations, attaches to different degrees of loading. The assumptions which are usually made have a fallacious character of precision.

Again, M. Bertrand points out that the analogy of urns and dice has been employed somewhat recklessly by Laplace and Poisson. It is true that the ratio of male to female births has a constancy such as the statistics of games of chance present. But, before we compare boys and girls to black and white balls taken out at random from an urn, we must attend not only to the average proportion of male to female births, but also to the deviations from that average which from time to time or from place to place may be observed. The analogy of urns and balls is more decidedly inappropriate when it is applied to determine the probable correctness of judicial decisions. The independence of the judges or jurymen which the theory supposes does not exist.

> "Quand un juge se trompe il y a pour cela des raisons: il n'a pas réellement mis la main dans une urne où le hazard l'a mal servi. Il a ajouté foi à une faux témoignage, le concours fortuit de plusieurs circonstances a éveillé à tort sa défiance, un avocat trop habile l'a ému, de hautes influences peutêtre l'ont ébranlé. Ses collègues ont entendu les mêmes témoins, on les a instruits des mêmes circonstances, le même avocat a plaidé devant eux, on a tenté sur eux la même pression."

With equal force does M. Bertrand expose the futility of the received reasoning by which it is pretended to determine the probability that the sun will rise to-morrow from the fact that it has risen so many days in the past.

These reflections are just and important; but their value is somewhat diminished by the fact that they have been, for the most part, made by previous writers with whom our author seems unacquainted. Thus Prof. Lexis has more carefully considered the extent of the error committed by Laplace and Poisson in applying to male and female births and other statistics rules derived from games of chance. The fundamental principles of Probabilities have been more fully explored by Dr. Venn. M. Bertrand, like Laplace, starts by defining the probability of an event as the ratio of the number of favourable cases to the number of possible cases. He does not explain what constitutes a "favourable case"—that, when a die is thrown, the probability of obtaining the 3 or 4 is one-sixth, because as a matter of fact each side in the long run turns up once out of six times. Accordingly, when he argues that in a great number of trials each event is most likely to occur with a frequency correspond-

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